FIREFIGHTER ROBOT

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ALHAJRI'S TEAM
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1. Introduction:

a. <u>Description</u>

Fires are a threat to both human life and property. According to the national fire administration 39% of all fires are structural fires. These type of fires result in significant loss of lives, injuries and destruction of property worth millions of dollars. The state has put in measures to curb the devastating destruction of fires through policies and agencies dedicated to respond to fires like the fire departments.

b. <u>Motivation:</u>

Fire fighter try their best to respond quickly to cases of fires and even put their lives at risk as they endeavour to save human life and protect property from fires.

Some attempts have been made to automate fire fighting for the navy (Shipboard Autonomous Firefighting Robot, n.d.), (firefighting robot, n.d.)

c. <u>Functional statement</u>

Even though the men and women working in the fire department are well equipped and trained, more often than not, due to the unpredictable environment created by fires, the fire fighters end up being injured or even die in course of performing their duties.

This is undesired in this current technological space. Fire fighters should have better working conditions to make their work safe and efficient.

d. <u>Requirements:</u>

To design and manufacture a firefighting robot

Specific objectives:

1. To design and implement a test environment
2. To design and implement an alarm system
3. To design and implement a fire detection system
4. To design and fabricate the frame of the robot
5. To design and implement a water dispensation system
6. To design and implement the drive system
7. To design and implement the control system

Constrains:

I. The robot cannot climb stairs
II. High skills required to implement some sections.

III. Some parts like the rubber wheels will melt at high temperature

e. Engineering Merit:

The desired features include:

To have a robot that can be remotely navigated by an operator hence removing the human element from the harsh conditions of a burning area.

To have a camera providing adequate vision of the burning building/ structure to aid in directing the robot to put out fire in the appropriate location.

To have a well calibrated sensors and accuracy and sensitivity to detect fires with precision

To have a robust robot body that protects the circuitry from the high temperatures

To have an efficient water dispensation mechanism with the capability of putting out the fires from a close or from the desired distance.

f. Scope of Effort:

The 2solution is to build a robot with considerations of the power capability to power the entire electronic circuit, motor drivers and the water pump. The robot has to have fire resistant materials that are also easy to manipulate during the frame and body fabrication in its construction. The material should also offer some weight advantage in that it should not be heavy. An example of such a material is carbon steel A36, it has high tensile strength to withstand impact from falling materials. (ASTM A36 Steel Plate, 2015).

The robot drive mechanism has to have enough torque and power to enable it carry its entire payload without being cumbersome. Also, the robot will have a speed controller to aid in navigation and steering.

The control of the robot should be facilitated with a good signal strength to enable adequate range of use by the operator.

g. **Success Criteria:**

The ROBO Team has planned on how to implement this project. Each member has been assigned a task while doing continuous research to ensure the success of this projects. With the right amount of funds, this project can be further pursued and improved.

2. Design and Analysis:

a. ***Approach: Proposed***

Many fire fighters lose their life each year while fighting against the fire. The job is really hard and requires lot of stamina and accuracy. A much amount of budget is used for fulfilling the loss and still the risk factor of doing this job is quite high. The approach of this project is quite simple. A firefighting robot will be using a sensor in it to sense the fire and it will be able to throw the water in the particular range. The water will be thrown with same pressure as it is thrown by usual fire fighter. Analysis are presented in the appendix A while the appendix B is showing dimensions of the whole project.

b. ***Design Description:***

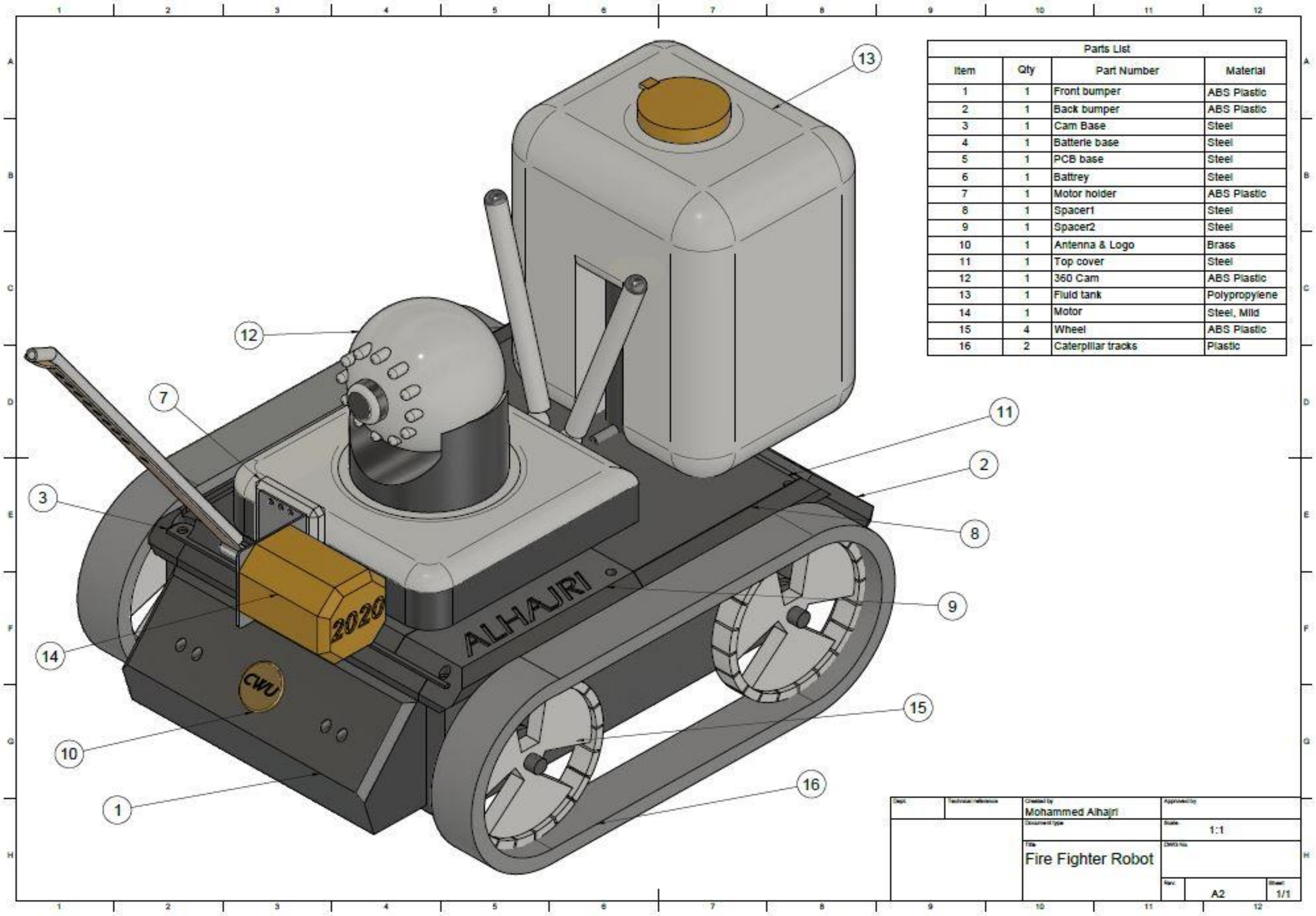


Figure 2: Fire Fighter Robot

Human life is the most important thing. In the age of technology efforts should be done in which risky jobs should be given to machines. There will be a camera and water throwing arm which will be attached with the upper part of the project. The team will be handling only the mechanical part of the project.

c. ***Benchmark***

The movement of the cart depends on the proper programing in the software portion. The cart must be used for small level fire.

d. ***Performance Predictions:***

- The cart will sense the presence of fire.
- The cart will locate the fire by its camera.
- The water will be thrown to the fire within 2 seconds of detecting the fire in a distance more than 2 meters.

e. Description of Analyses:

Analysis is given in the Appendix B1 and B2.

f. Scope of Testing and Evaluation:

All of the parts of cart will be checked and evaluated that either they are working mechanically correct. Parts will be ordered online and they will be checked whether they are working or not on delivery. Also it will be checked that either they are exactly with the same model as it were ordered

g. Analyses:

The water tank pressure of the cart will be checked through the formula

$$P = 0.433 * height$$

This is how the pressure of the water tank will be calculated.

The velocity of water coming from the water tank will be estimated with the use of the formula

$$velocity = \frac{Distance\ Covered}{Time}$$

The distance covered by the water after coming out of the valve will be calculated in meters. The time will be calculated in seconds. The unit of velocity will be in meters per seconds.

The force on the hose will be calculated through the formulas

$$F = \frac{C_D A P v_2}{2}$$

The value for this particular system will be kept at 0.00425. Area calculations will be done through the dimensions of the pipe.

h.

The parts of this project will be fluid valve, fire extinguisher, robotic arm, chained wheel, cart and battery. Shape of the cart will be flat from the top and curved from the sides. Bottom plate will be smaller than the top one.

i.

Wheels, water tank, chain, fire extinguisher and camera will be present in the final assembly. All will be joined at the particular positions as this is shown in the SOLIDWORK design.

j.

The tolerance value for all the connections in assembly will be under 5%. Highest accuracy will be tried to achieve so that the project can function according to the objective.

k.

- Can stop working in damp conditions.
- Schedule risk
- Cost Risk
- Analysis method maturity
- Equipment and material availability
- Materials uncertainty.
- Funding constraints

3. Methods & Construction

a. Methods

- 3D modeling all top parts with drawings.
- Buying all the necessary parts for the top suction of the robot such as a 360 degrees' camera and fluid tank with pump from online stores such as Amazon.
- 3D printing all the other top parts such as the camera base.
- Testing the geometry and durability of the parts before assembly.

- Each part has its own purpose for the bottom section of the robot.

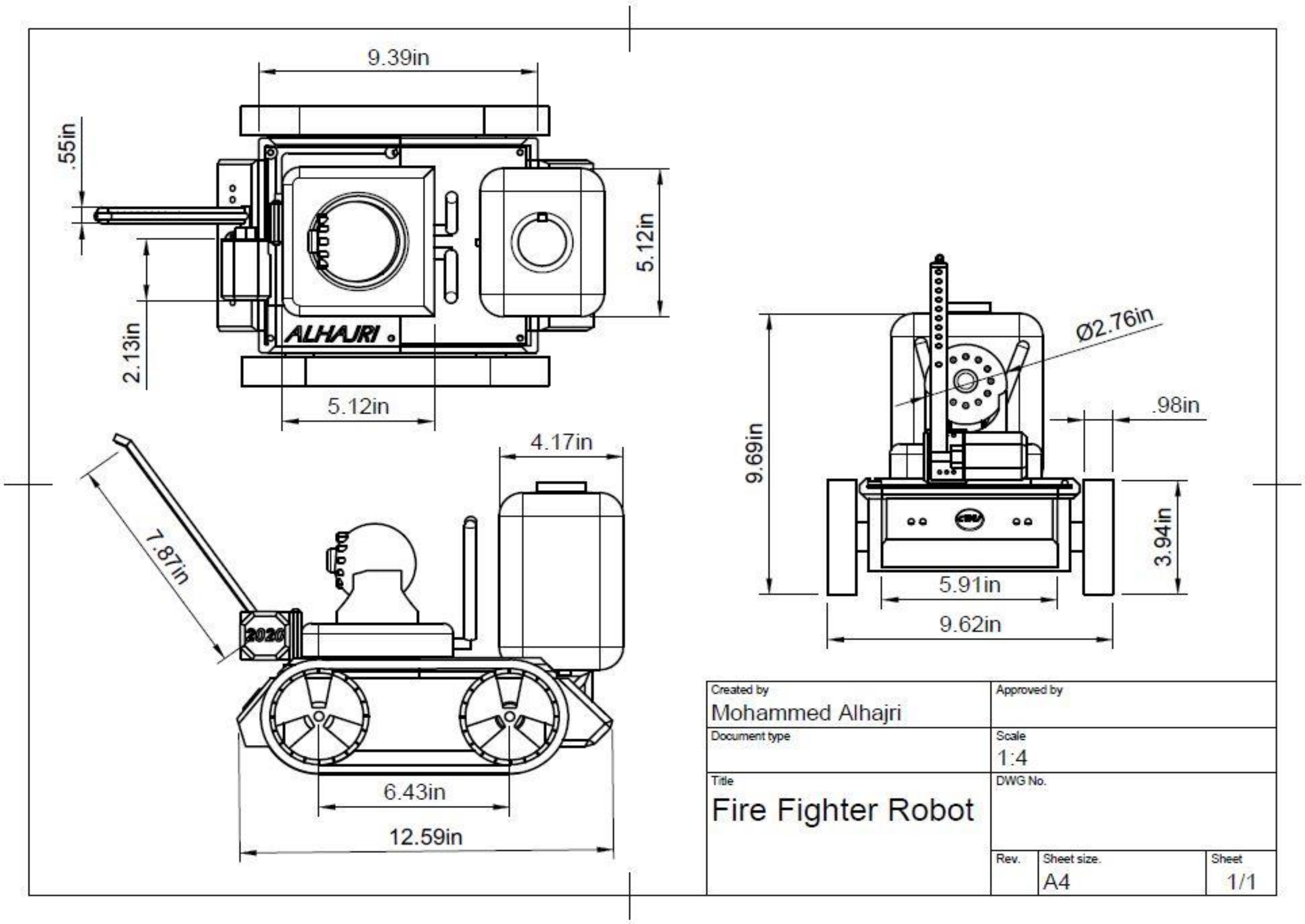


Figure 3: Top View of the Project

The arm is showing clearly in the picture which will be able to throw the water on the fire. Also the camera is attached in the top part. This camera will act as an eye for the whole cart. After watching the fire, the signals will be transmitted and the cart will follow the fire. The tanks on the cart are the fire extinguishing tanks. The valve of the extinguishing tanks will be controlled by the team. The camera fitted at the top will be wide angle camera. There will be two parts of the project. There will be electrical part and the mechanical part. This team will be doing the mechanical part in which proper dimensions of the wheel, chain, shaping of the whole cart and the placement and movement mechanism will be done.

b. Construction

Part	Made by	Description
360 degrees camera	Online store	The eye of the robot that able to look in all directions with night vision can be monitored and controlled wirelessly by a smartphone.
Motorized arm	Online store	The arm that will guide the fluid tube nozzle in upward or downward position.
Fluid Tank	Online store	About a gallon of fluid tank with its own 12V pump and 24 inches long 0.25 inches tube.
Front Spacer	3D Printer	To make enough space between the top cover and the chassis so the battery can fit and it holds the battery from its sides
Back Spacers	3D Printer	The same as the front, to raise the top cover from all sides.
Camera base	3D Printer	To hold the camera on the top of the chassis in position. Also it holds the motorized arm on the front top of the robot.

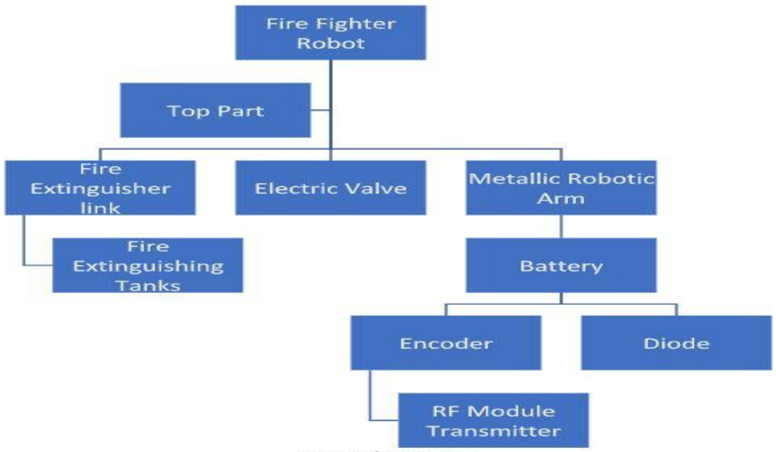
i. Description:

There will be water tank that will be placed on the top of the cart. This will carry the water that will be thrown over the fire.

ii. Manufacturing Issues:

- Incompatible water tanks
- Narrow angle camera
- Wrong Welding Technique

iii. *Drawing Tree, Drawing ID's:*



Drawing Tree
Fire Fighter Robot (Top Part).

Tree 1

iv. Parts Lists and Labels

i. Fluid valve

ii. Fire Extinguisher

iii. Robotic arm

v. Discussion of assembly.

Drilling will be done on the platform on which the upper part of the project will be placed. The water throwing arm and the water tanks will be connected.

- ***Manufacturing issues/modifications:***

- The top section of the Fire Fighter Robot has three main parts which are the 360 degrees' camera with night vision feature, fluid tank with 12V pump and the robotic arm. All these parts will be attached to the top of the robot chassis by custom design fixtures/widgets which are made from plastic by a 3D printer. The main fixture/widget on the top of the robot is the camera base widget which will hold the camera and the robotic arm at the same time. However, this widget or the other 3D printed parts must be made with intolerance with flat, parallel and perpendicular surfaces according to the drawing datum. At the first time of printing the camera base widget, it came out of the printer with bent surfaces which cannot be used as it won't fit on the chassis. To solve the tolerance and flatness issue, the 3D printer timing belts for the X and Y axis were tightened, the Z offset was lowered by 0.01mm than it was and more glue stick was added to the printer table, then the result came perfectly.

- To test the full functionality of the Fire Fighter Robot, the top section and the bottom section was tested spritely. The top section has three main parts, the robotic arm, the camera, and the fluid tank with its pump. All the top parts were fully functional during and after the test without any technical issues. The robotic arm was successfully functional as it can move upward and downward as it should be. The 360 degrees' camera was fully able to be controlled by the app in the smartphone via Wi-Fi, with only 500-millisecond delay and connection range around 94 meters. The fluid tank's pump was successfully able to pump fluid to the nozzle and can reach 2 meters away from the robot. The robot was fully functional with a wireless connection range was more than what was expected. The only issue that might reduce the connection range by 50% or even to 100% if the robot was controlled over isolating walls such as thick concrete and masonry walls. Overall, the Fire Fighter Robot was and still fully functional as it was intended.

- The top section of the Fire Fighter Robot was successfully functional as it was expected, but there is still a large room for improvement. All the top section parts can be upgraded, but the total price of the robot might increase to %100 or even more if high-quality parts were used. One of the main components that can be upgraded in the top section is the camera. The current camera on the robot was bought for $60. it is functional, but it does not deliver high-quality video and doesn't have a long-range wireless connection with the smartphone. Also, the camera is not a water resistance or high heat resistance, which might shorten its life cycle. A more expensive camera such as $150 or higher with a famous brand, is better than the current camera when it comes to water and heat resistance, connection signal, and video quality. Still, the current camera and top section parts are doing their job correctly at the lowest affordable price.

4. Testing Method

a. Introduction:

Basic methods of testing will be used in the project. The throw from the electric fluid valve will be checked. Any fault in the rotation of the arm will be checked.

b. Method/Approach:

Simple calculus techniques and physics formulas will be used. After finding the values of the required variables they will be placed in the equation and the results will be used to make the improvement in the project.

c. Test Procedure description:

Introduction:

The top section of the Fire Fighter Robot has three main parts which are the 360 degrees camera, fluid tank and robotic arm. All the top parts will be tested at the same time as they all controlled by a remote with a smartphone in it. The camera should have a simple Wi-Fi connection access with the smartphone. the fluid tank pump should be able to spray water for at least one meter for when the button is pressed on the remote. The robotic arm should be able to lift the spray nozzle upward and downward when the button is pressed. a measuring tape will be used to measure the spray range and the remote connection range. A measuring cup will be used to measure how much fluid coming out of the nozzle per second.

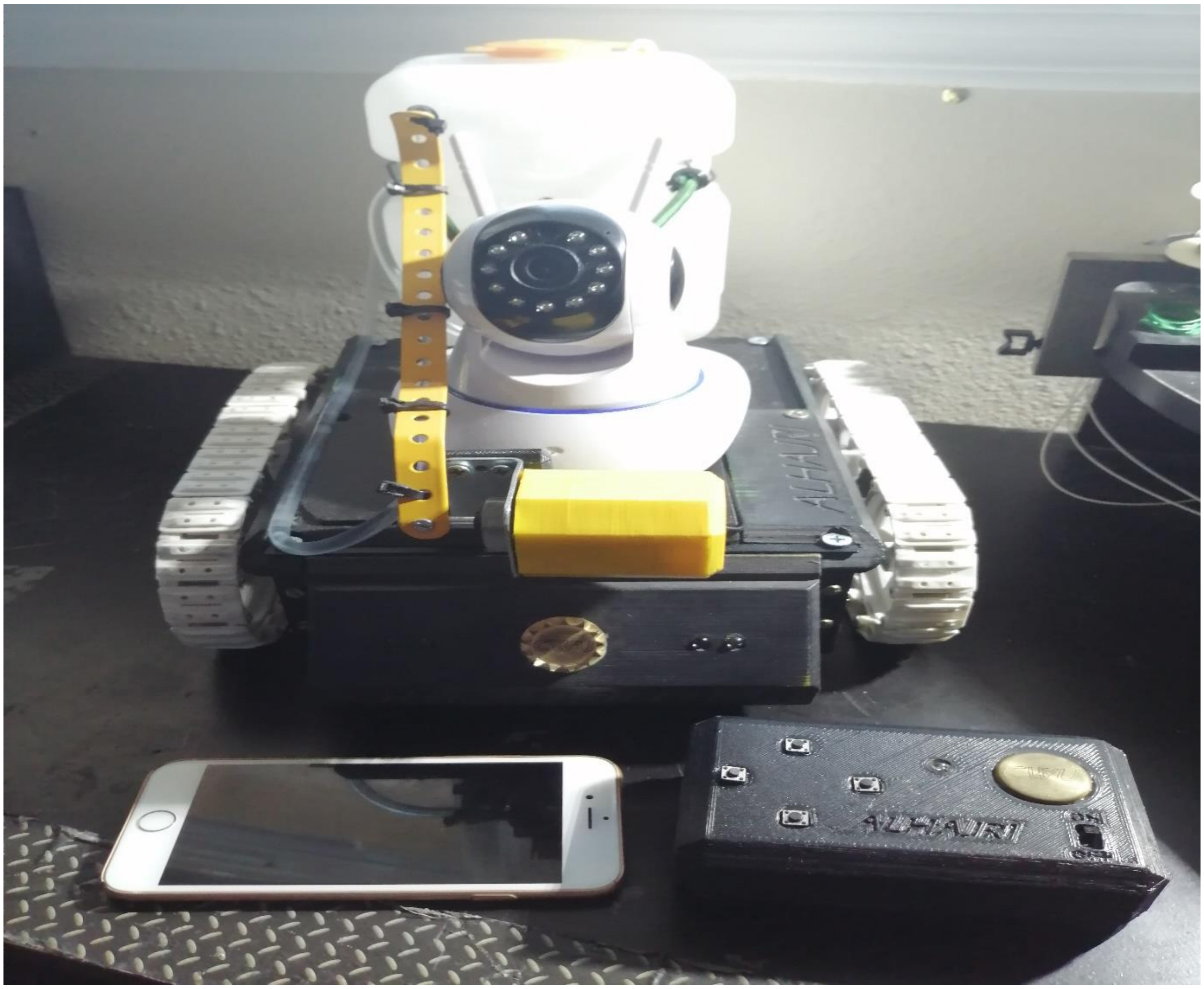
Method/Approach:

The wireless remote with the smartphone in it, is the most important part to complete the test. if the remote fails, nothing on the robot can be operated or tested as everting in the robot is connected to one main PCB with a microcontroller that controlled wirelessly by the remote. Nassar Alhaddad is an experienced engineer specializing in the electronics filed. He can easily troubleshoot and locate the issue in the remote or the main PCB as it hard to locate the familiar, whether from the remote or the main PCB

Test Procedure:

- Three main parts to complete the test:

The Robot – The Remote – A Smarphone



- The test should take less than two hours to test the whole robot.
- Place: Office.

- **Test Steps:**

1- Place the smartphone in the remote tope slot as shown below.

2- Turn on the Remote from the switch.

3- Turn on the Fire Fighter Robot.

4- Turn on the smartphone and login into the V380s app.

5- Slide/touch on the smartphone screen to rotate the camera.

6- Press the left and right buttons for two second to switch from rover mode to robotic arm and spray mode. See image below.

7- Now by pressing the top button the robotic arm should go upward and downward when the bottom button was pressed.

8- When pressing the left button, the nozzle should spray water while in spray mode.

9- Keep the nozzle upward after using it by pressing the upward button.

10- Switch back to rover mode by pressing the left and right button at the same time for two second.

11- Turn off the Robot.

12- Turn off the wireless remote.

- The progress of testing the functionality of the robot went very well as it was expected with no risk involved.

Deliverables:

The 360degrees camera worked very well with the app in the smartphone by an automatic wife connection with no need to set up. The fluid tank pump was able to spray water for 2 meters long and the flow rate was 10 FL OZ/s, which is more than what was expected. The robotic arm was successfully able to lift the nozzle upward and downward with no issue. Overall, the test was passed and robots is completely functional without any issues.

e. Full performance test after assembly.

- The Fire Fighter Robot was successfully assembled from the first time without any issues from the 3D printed and retailed parts. After the robot was assembled, it was tested in performance by running it for around two weeks. The top section parts of the robot which are the tank, the camera and the robotic arm was running without any issue controlled by the radio remote. The fluid tank's pump was powerful enough to spray water over 2 meter away. The robotic arm can easily rotate by 100 degrees and lift the tube and nozzle filled, but the robotic arm holder which was made by a 3D printer, was not strong enough as it was broken during the test. A new robotic arm holder was 3D printed again with higher infill density from %10 to %25 infill. The 360 degree's camera with night vision was successfully assembled to the camera base widget and connected to a smartphone and tested the camera

360 rotation by the app and the night vision feature by placing the robot in a dark room. After all, the Fire Fighter Robot was running as it was expected before it was assembled and there are rooms for future improvements in the whole project but that all rely on the budget.

- After the Fire Fighter Robot was fully assembled and used for around two months, it was still functioning as it was before with no newer issues. Also, there is room for more improvement in the design and parts. The test has successfully met the requirement for the Fire Fighter Robot to function as it should be. There are three main parts that were tested for the top section of the Fire Fighter Robot. The main parts that were tested were: The fluid tank, the 360degrees camera, and Robotic arm. All the parts were tested by using the wireless remote of the Fire Fighter Robot. If the wireless remote failed to operate correctly, the test would fail for all the three parts of the top section of the robot. Luckily, the remote was correctly working. After turning on the remote and placing the smartphone in the remote slot, the 360 camera app got connected successfully to the camera on the robot with only two seconds delay. The camera was able to perform 360 degrees' movement by the app in the smartphone by touching the screen upward, downward, left and right without any issues. The camera app connection range was around 150 feet, which was very useful to be able to operate the robot from a long distance. By pressing the left and right button at the same time for one second, the robot switched from running mode to spray mode, which will activate the robotic arm and the fluid tank pump. While the robot on the spray mode, after the forward bottom was pressed, the spray nozzle, it went upward by the robotic arm, and when the bottom button was pressed, the nozzle went downward without any issues. When the left bottom on the remote was pressed, the nozzle started to spray water that can reach two meters away and one-meter high. The spay nozzle hole was 4mm; if a smaller nozzle was used, such as 1mm, it will be able to spray for around 4 meters. Overall the whole test met the requirement and was fully functional is it was expected.

5. Budget:

i. The parts as well as the estimated cost is given below

PART IDENT	**PART DESCRIPTION**	**SOURCE**	**COST APPROX. (USD)**
Fluid Tank	DN15-DN80 OD. 20 mm L= 5 mm	Amazon	$20
360 Camera	WiFi 360 Camera controlled by smartphone	Amazon	$40
3 motors	Low RPM, High torque gear motors 12V	Amazon	$150
Chained Wheel	52 Chain links L = 13 cm	Amazon	$25
Cart	Weight = 33 lb Max Load = 10 kg L = 8 cm W = 6 cm H = 3 cm	Amazon	$110
Battery	ExpertPower 12V Lithium Acid 8AH	Amazon	$25

i. ***Determine labor or outsourcing rates & estimate costs***

Labor for making this project will be the team members of this project.

ii. ***Labor***

Team members itself will be the labor for this project.

iii. Estimated total project cost of this project will be 375 USD. This will be the cost of making the purchases for the parts of the project.

iv. The team of this project will make the contribution in purchasing all the items of this project. So funding source will be the members of the project team.

v. Actual Cost and Cost Change:

- The top section of the Fire Fighter Robot costs had an initial budget of $215 for its parts. The total money spent from the budget to this point is $183 which is %85. The total money left from the budget is $32. To this point, all the top section parts were bought and manufactured for the robot and ready for assembly. After the robot being assembled, helpfully it will function well after the test to avoid spending more money on modifications or parts failure. The main parts for the top section with their price including tax and shipping were the camera for $40, fluid tank with its bump for $20 and the 3 geared motors for $90. During this Winter season, the 3 geared motors became cheaper than before as they were for $150 instead of $90 and they all were bought in the first week of Jan 2020 as it is shown below in the budget history table. In the second week, $20 was spent on the 3D printer filament for the spacers and the camera base and both of them were not printed with the correct diminutions. As there was enough filament, they were edited and reprinted without extra expenses. $18 were spent on spray paint and blank PCB and that was the last purchase for the project.
- Budget history:

Date	Money Spent
PSR# 01 01/05/2020 – 01/12/2020	$145
PSR# 02 01/12/2020 – 01/19/2020	$20
PSR# 03 01/19/2020 – 01/26/2020	$8
PSR# 04 01/26/2020 – 02/02/2020	$10
PSR# 05 02/02/2020 – 02/09/2020	$0
Total budget spent so far =	$183

- After the top section of the Fire Fighter Robot was fully assembled and tested, the budget was not affected as much. While testing the durability of the whole assembly of the Fire Fighter Robot, the 3D printed robotic arm holder got broken as it couldn't handle the weight of the arm. The robotic arm holder was made with 20% plastic infill density which was not enough infill to make the holder strong as it should be. On 02/23/2020 – 03/01/2020 period, a $10 was spent to buy a new filament for the 3D printer to remanufacture/reprint the holder with higher infill density as high as 50%. After the holder was reprinted, it was reassembled and tested and was durable and was very stiff as the holder was relatively small compared to the other printed part. other than the $10, there wasn't another issue or the need for the top section to spend money on. The current budget is $22 and the starting budget was $215.

- Budget history (updated):

Date	Money Spent
PSR# 01 01/05/2020 – 01/12/2020	$145
PSR# 02 01/12/2020 – 01/19/2020	$20
PSR# 03 01/19/2020 – 01/26/2020	$8
PSR# 04 01/26/2020 – 02/02/2020	$10
PSR# 05 02/02/2020 – 02/09/2020	$0
PSR# 06 02/09/2020 – 02/16/2020	$0
PSR# 07 02/16/2020 – 02/23/2020	$0
PSR# 08 02/23/2020 – 03/01/2020	$10
PSR# 09 03/01/2020 – 03/08/2020	$0
PSR# 10 03/08/2020 – 03/16/2020	$0
PSR# 11 04/01/2020 – 04/13/2020	$0
PSR# 12 04/03/2020 – 04/19/2020	$0
PSR# 13 04/19/2020 – 04/26/2020	$0
PSR# 14 04/26/2020 – 05/04/2020	$0
PSR# 15 05/04/2020 – 05/11/2020	$0
PSR# 16 05/11/2020 – 05/18/2020	$0
Total budget spent so far =	$193

6. Schedule

a. Gantt Chart is present in Appendix E.

b. Specific tasks in this chart is

- Number of hours required for finishing each task like
- Proposal
- Analysis
- Documentation
- Proposal Mods
- Part Construction

The due date of proposal is given as 6th of December.

c. The task of submitting the proposal will be completed by the 6th of December. Second task will be working and building the project of Fire Fighter Robot which will be started on 20th of January.

d.

- Submission of the proposal is the first deliverable.
- Submission of the analysis section with 12 green sheets is second deliverable.
- Manufacturing and construction of project is the third deliverable which will be started in the mid of January
- The completion of the whole project is forth deliverable which will be completed within two and half months.

e. Estimated total project time will be 190 hours.

f. Gantt Chart

This is attached in Appendix E.

g. Manufacturing schedule issues/changes:

The schedule of the top section of the Fire Fighter Robot which is the Gantt chart in Appendix E was designed in the fall quarter. During the analysis of the project top section parts, few elements were added to the schedule as well as the actual duration hours got typed in for most tasks. The first task for the proposal and the second task for the analysis were done on time, but the actual duration hours were more than what was estimated by ten hours more for each of the first two tasks as it is shown in the chart. The third task for the documentation which includes the parts drawings mostly was done ahead of time and took fewer hours than the estimated by ten hours less. Also, few new drawings that also was done on time were added to the third task such as the camera and the fluid tank. The fourth task for the proposal mods and seventh for the part construction were also done ahead of time and took less duration hours by twenty hours less than the estimated duration.

All the tasks in the schedule for the top section of the Fire Fighter Robot project are almost done as it was scheduled for. The 9th task was for the device construction and was done on time with the same estimated time except the 9f job, which took fewer actual hours for the website update. The tenth task section was for the devise evolution of the robot, was done in 27 hours, which was six hours less than has been estimated. Also, the 10th task was successfully done ahead of its time, and it saved time for the investigator to fix issues if there was any. The 10g job took three hours more than what was estimated because, at that time, the robot ran into some wireless connection issues. Thankfully, the team mentor Nassar Alhaddad was able to fix the problem by replacing the radio receiver module on the main PCB to a newer one after he troubleshoots the robot's leading PCB and the remote. The old receiver module failed because of the overheat from the voltage regulator, as it was very close to it. The overheat issues were solved by adding a fan to the inside the robot's chassis to cool down the whole PCB/the robot's brain. The 11th task for the 495 deliverables was 50% done on time without any issues, as shown in the Gantt Chart in Appendix E. Making the CD for the project and updating the website for the last time, are the only jobs left from the 10th task section.

7. Project Management

a. *Human Resources:*

Mohammad Alhajri the student of the Mechanical Engineering will take care the top part of the project. Sultan Alhajri will be the partner who will take care the bottom part of the project. Electronic engineering tech. department at CWU will help doing the electrical part.

b. *Physical Resources: Machines, Processes, etc.*

- Drilling Machine
- 3D Printing
- CNC machining
- Metal cutter
- Saw
- Holding Clamp
- Spanner
- Nuts

- Hammer

Some of the processes are

- Cutting
- Sawing
- Drilling
- Machining

c. ***Soft Resources: Software, Web support, etc.***

- SOLIDWORKS
- Fusion 360
- YOUTUBE videos

d. ***Financial Resources: Sponsors, Grants, Donations***

Only team members of project will pay the whole cost of the project.

8. Discussion

a. ***Design Evolution / Performance Creep***

During the starting part of the project the team will design and fabricate the frame of the whole robot. After cutting the parts they will be joined according to the design which has been made in SOLIDWORKS / Autodesk Fusion360. After the proper connection the robotic arms and the water tank will be attached with the top plate of project. The control valve for water will be attached at the end.

b. ***Project Risk analysis:***

The top risk in this project will be receiving he injury during the machining part of the project. The second highest risk will be receiving the cut in fingers while sawing the aluminum metal. Proper training for the machining and sawing will be required or the risk of receiving injury will increase.

c. Successful

The project will be said as the successful one if the robotic arm will be fixed in the right place. Also the successful connection between the valve and water tank will be necessary for the project to make it work successfully.

d. Project Documentation:

The documentation of the project will include the upper part plate design, the camera design, water tank design and the control valve design.

e. Manufacturing:

Next phase of the project is manufacturing the whole project according to the design and the dimensions. The whole construction process will be done in

f. ***Design Manufacturing Issues / Modifications:***

The top section of the Fire Fighter Robot has multiple parts that need to be secured on the top of the chassis. The parts are the fluid tank, the camera and the robotic arm that controls the position of the fluid nozzle. However, these parts have odd bottom shapes which make it difficult to install them securely on the top plate/cover of the chassis. Also, the top plate doesn't have enough room to take the whole bottom base of the fluid tank. Three widgets/parts have been 3D designed to make all these parts secured in place. As there isn't enough room for the fluid tank, the back bumper 3D printed widget top face was designed for the fluid tank bottom to clamp on it. The Camera Base is a 3D printed widget that will hold the camera like a fixture, as the top surface of the base has the same face as the camera bottom face. Also, the camera base/widget holds the robotic arm in position in front of the camera vertically so the arm doesn't hit the camera.

After the Fire Fighter Robot was fully assembled, it has been used for more than two weeks to make a full performance and construction durability test. a couple of issues in the top section of the robot and its remote controller appeared during the test. The issue in the top section was from the robotic arm holder widget, as it wasn't denned enough to hold the robotic arm, so it was reprinted by 15% extra infill density and that solved the issue. The other issue was from the remote controller of the robot as the Forward and Right buttons didn't function at all. After troubleshooting the remote circuit board, there was a tiny short between the two buttons which made them both share the same output and the microcontroller didn't response to the request of the button. The remote controller issue was resolved by scratching away the circuit-short trace on the PCB.

9. Conclusion

a. Design title and its complete design readiness.

The design title of this project is "Fire Fighter Robot". As the team is doing the mechanical part for this project so the final product will be moveable on floor. The whole connections of the parts will be assembled with the correct dimensions. The chain and wheels will be attached with the tank. The water tank will be attached on the top part.

b. Important analyses and how this contributes to success.

The important analysis of this project will be velocity of water analysis as it come from the water tank, force on robotic arm with the water velocity, cylinder characteristics and cylinder dimensions, water tank pressure, water tank stress, and water flow calculations. The right choice of each will help to increase the efficiency of Fire Fighter Robot in controlling the fire.

c.

- The cart will sense the presence of fire
- The water will be thrown to the fire within 2 seconds of detecting the fire.

Acknowledgement

This is acknowledged to all people who assisted during the completion of this proposal.

The faculty members of the department of mechanical engineering and especially the instructor who provided the guidance throughout the process of completing the proposal. Thanks to all for the support.

References

Arduino based Fire Fighting Robot using falme sensor. (n.d.). Retrieved December 5, 2019, from https://create.arduino.cc/projecthub/130797/arduino-based-fire-fighting-robot-using-falme-sensor-4e0556?ref=user&ref_id=447872&offset=0.

Han, A. (2019, April 17). Meet the Robot Firefighter That Battled the Notre Dame Blaze. Retrieved December 5, 2019, from https://www.popularmechanics.com/technology/robots/a27183452/robot-firefighter-notre-dame-colossus/.

Appendix A Analysis

AppendixA1-Calculating the velocity from Fire extinguisher and robotic arm thickness.

Mohammed Alhajri | MET 499A | 10/18/2019 | 1

Fire surface = $20 m^2$

Thickness of flammable liquid layer = 1 cm

Preburn time = 25 s

Extinguishing time = 35 s

Measured foam expansion = 6.5

Fire spreading time on whole surface = 10 s

Total time of foam introduction = 120 s

Foam blanket thickens at the end of foam introduction = 0.1 m

Penetration velocity = $30 \frac{m}{min}$

Total foam solution amount used = $9 m^3$

Average foam solution intensity = $8.85 \frac{l/min}{m^2}$

Average intensity estimated during extinguishing time = $16.8 \frac{l/min}{m^2}$

Robotic Arm minimal wall thickness = 45 mm

Weight of arm = 116.8 kg

Velocity from Fire extinguisher = $0.408 \frac{Q}{D^2}$

Q = 5 gpm

D = 3 in

Velocity from hose = $\frac{0.408 \times 5}{3^2}$

$= 0.2266\ ft/s$

AppendixA2: Finding FD

$F_D = C_D \, A \, \frac{\rho v^2}{2}$

F_D = Resistance drop farn

$U = 0.2266$ ft/s

$\rho = 1000$ Kg / m^3 = 0.0163 Kg / m^3

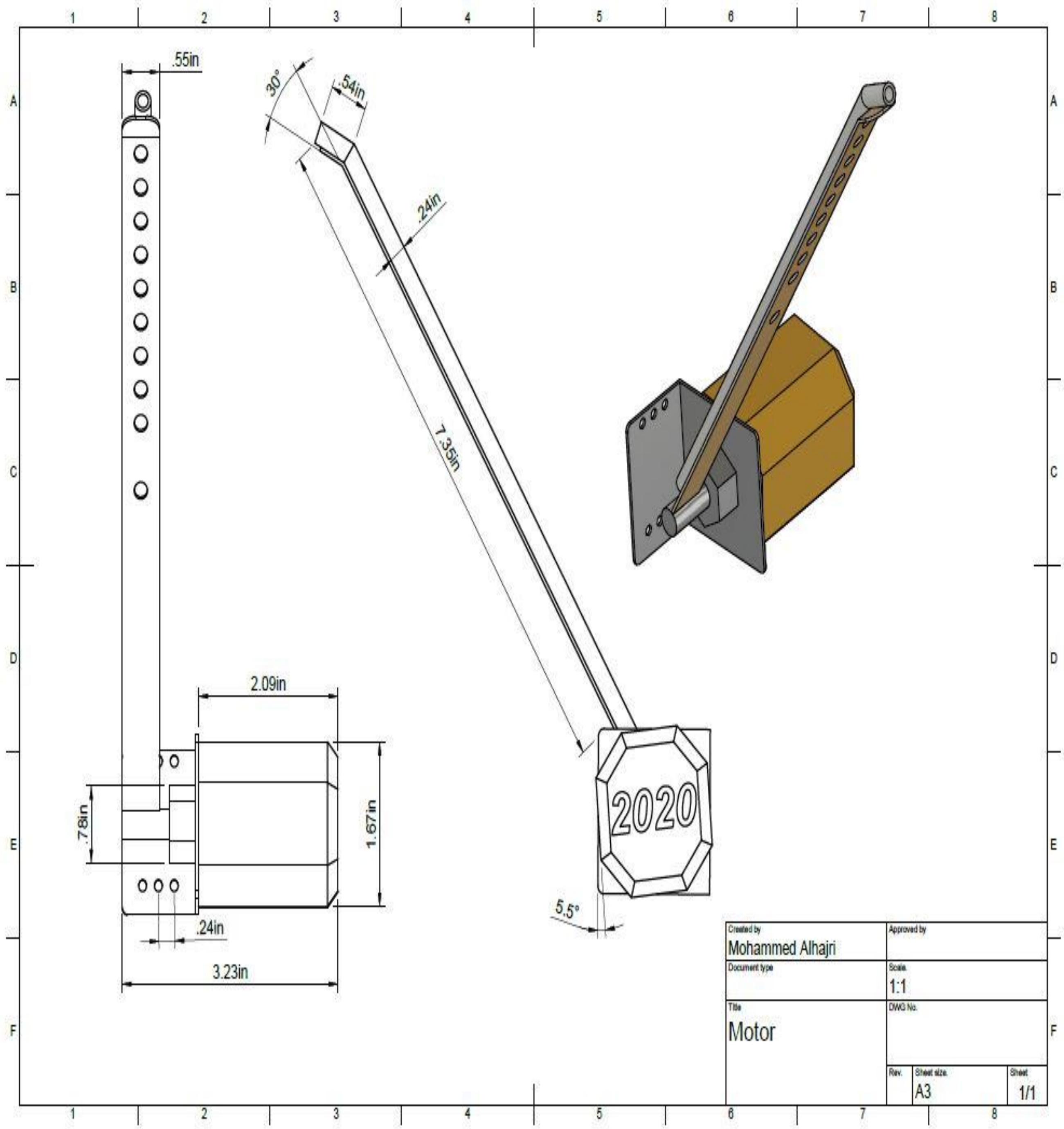
$A = \frac{\pi}{4} d^2 = \frac{\pi}{4} (3)^2 = 7.065$ in^2

$C_D = 0.00425$

$$F_D = \frac{0.00425 \times 7.065 \times 0.0163 \times 0.2266^2}{2}$$

$$\boxed{F_D = 1.256 \times 10^{-5} \text{ lbs}}$$

AppendixA3: Drawing the robotic arm and fire extinguisher



Appendix A4: Top Part (Fire ExtinguisherSpecs).

Mohammed Alhajri | MET 497A | 10/29/19

Time of extinguishing = 35 s to 40 s

Preburn time = 30 s

Surface Coverage = 25 m^2

Liquid layer thickness = 1.5 cm

Ratio for foam expansion = 7:4

Time for spread = 12 s

Introduction foam = 110 s

Blanket of foam thick = 0.2 m.

Velocity of Penetration = 32 m/min

Volume of foam = 12 m^3

Intensity of foam = 8.67 l/min/m^2

Extinguishing time intensity = 15.5 l/min/m^2

Wall thickness = 55 mm

Arm weight = 155 kg

Night vision camera = 200 g

Theorem of fire = $0.408 \frac{Q}{D^2}$

D is the diameter = 7 in

Q is in gallon per minute = 6 gpm

Water velocity = $\frac{0.408 \times 6}{7^2}$

= 0.0499 ft/s

Apprndix A5: Force on arms with water velocity.

Force on Arms = $\frac{CD\ A\ \rho V^2}{2}$

Water velocity = 0.0495 ft/s

$CD = 0.00425$

Area of the hose = $\frac{\pi}{4} \times 7^2$

$= 38.46\ in^2$

Density = $1000\ kg/m^3 = 0.0163\ kg/in^3$

Force on arm = $\frac{0.00425 \times 38.46 \times 0.0163 \times 0.01495^2}{2}$

$= \boxed{3.264 \times 10^{-6}\ lbf}$

Dimensions of fire extinguisher = 5in × 4in × 6in in

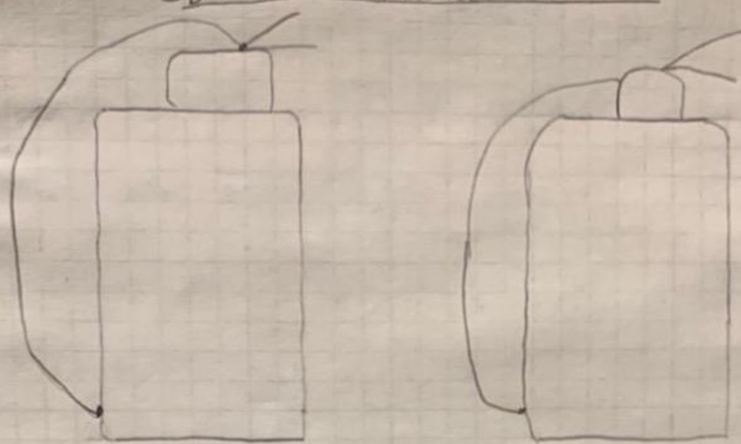
$= 120\ in^2$

Camera Dimension = 2×2×1 = 4 in^3

Appendix A-6: Fire Extinguisher Characteristics.

Mohammed Alhajri | MET 489 A | 11/01/19

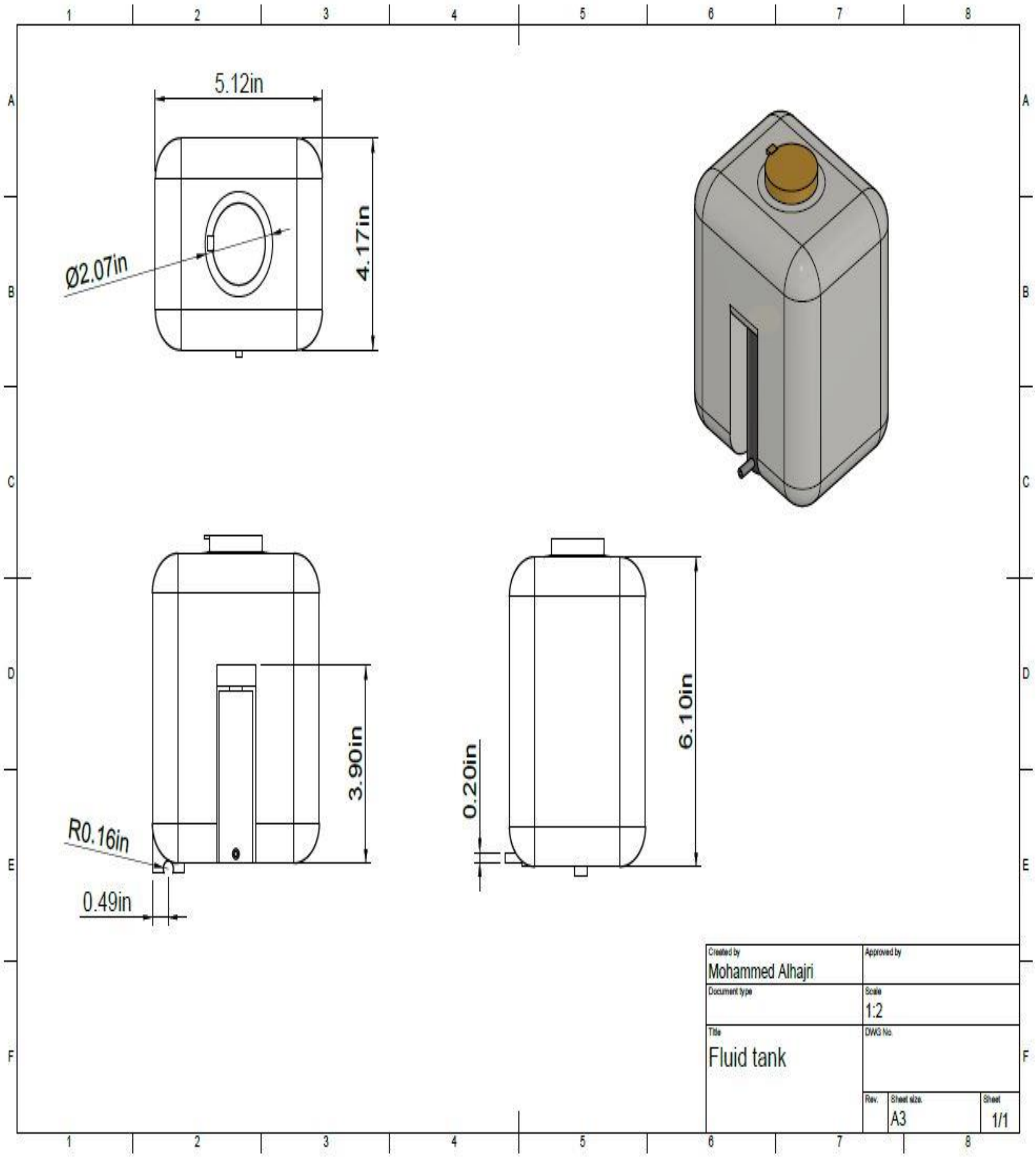
Cylinder Characteristics



Fire Extinguishers

1. Extinguishing time = 40 s.
2. Length of extinguisher = 2 feet
3. Diameter = 8 inches
4. Coverage surface = 20 m^2
5. Tolerance = $\pm$ 5 m^2
6. Nozzle dia = 2 inches
7. spread time = 13 s
8. Throw Range = 10 feet
9. Peneration time = 44 s

Appendix A-7: Fire Extinguisher Dimensions.



Appendix A-8: Cylinder Charactrestics.

Mohammed Alhajri | MET 418

Cylinder Characteristics

Extinguishing time = t = ?

$$Q = 1000 \left(\frac{t}{t_g} \right)^2 \quad — (1)$$

fast fire has $t_g = 150$

$$Q = 0.0444 t^2$$

$$M = 0.07\, \Phi\, P^{1/3} (Z - Z_0)^{5/3}$$

$$T_m = \frac{QP}{Mc_p} + t_0$$

$$V = \frac{M T_m}{P_0 T_0}$$

Rearranging (1) for t.

$$\frac{Q}{1000} = \left(t/t_g \right)^2$$

$$\sqrt{\frac{Q}{1000}} = t/t_g$$

$$Q = 0.04 \ ft^3/s$$

$$\sqrt{\frac{0.04}{1000}} = t/t_g$$

$$t = t_g \times \sqrt{\frac{0.04}{1000}}$$

$$= 150 \times \sqrt{\frac{0.04}{1000}}$$

$$= \boxed{0.9486 \ s}$$

$$V = \frac{x}{t}$$

$$V = \frac{20 \ ft}{0.9486 s}$$

$$= \boxed{21.08 \ ft/s}$$

AppendixA-9: Electrical Part.

Mohammed Alhajri | MET482A | 11/8/19 | P.1

(Electrical part)

Camera System = $30

Tractile Sensor = 3

Computer Bay = 5

Omnidirectional platform = 2

Battery = 2.5V

Current Ratings = 0.5A

Number of cells = 6

Screen: 8" x 7"

Tray = 2

Gripper = spices

Arm weight = 25 lb

Movement Angle ~ 250 degree

Dof Arm = 2

Axis grip = 1

Lasser Scanner = 8

Motor = 3 motors

Motor power = 8 w

Current = 1.2 A (DC)

Appendix A-10: Electrical Part.

11/8/·19 P.2

(Electrical Part)

TCP = 2 - joint control

Base Height = 3m

Weight = 200 kg

DoF = 3 DoF

Fingers = 4

Control Level = 3

Battery Loss = 0.02 W.

Leakage current = 0.009 W.

Appendix A-11: Water Tank Pressure.

Mohammed Alhajri | MET 489 A | 11/15/19

Water tank pressure

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$P = \frac{\text{weight}}{\text{Area}}$$

$$P = \frac{mg}{Ag_c}$$

$$P = \frac{\rho V g}{A g_c}$$

m = mass in lbm.

$g = 32.17\ f/s^2$

$g_c = 32.17\ \frac{lbm-ft}{lbf-sec^2}$

A = Area in ft^2

V = Volume in ft^3

ρ = Density of water in $\frac{lbm}{ft^2}$

$\rho = 62.4\ lbm/ft^3$

$h = 3$ feet

$$P_3 = 62.4 \times 3 \times \frac{32.17}{32.17}$$

$$= 187.2\ \frac{lbf}{ft^2}\left(\frac{1}{144}\right)$$

$$= 1.3\ \frac{lbf}{in^2}$$

Appendix A-12: Water Tank Pressure.

Mohammed Alhajri | MET 489 A | 11/15/19

Water tank pressure

During Motion of cart

throw range increase

Adjustable height = 5 ft

$$P_s = \frac{62.4 \times 5 \times 32.14}{32.14}$$

$$= 312 \times \frac{32.14}{32.14}$$

$$= \frac{312}{144} \frac{lbs}{ft^2} \times \frac{ft^2}{in^2}$$

$$= 2.16 \frac{lbs}{in^2}$$

$$\boxed{P_s = 1.7\ P_3}$$

Appendix A-13: Water Tank Stress.

Mohammed Alhajri | MET 489A | 11/20/19

Stress of tank

Volume of water = $4.7\ m^3$

Weight of liquid = $45 \times 10^3\ N$

Specific weight = $\frac{\text{Weight}}{\text{Volume}}$

Weight Representation = W

Volume Representation = V

Specific weight = w

$$w = \frac{W}{V}$$

$$= \frac{45 \times 10^3}{4.7\ m^3}$$

$$= 9.57\ N/m^3$$

Mass Density of water pump = ρ

Specific weight = 8.87×10^3

Acceleration Due to Gravity = $9.81\ m/s^2$

$$\sigma = \frac{F}{A}$$

$$= \frac{45 \times 10^3}{\frac{\pi d^2}{4}}$$

Appendix A-14: Water Flow.

Mohammed Alhajri | MET 489 A | 11/20/19

How far the water flow will reach

$$\rho = \frac{8.889 \times 10^3}{9.81}$$

$$= 906.1 \ kg/m^3$$

Specific Gravity $= 8.77 \times 10^3$

Specific Weight $= 9.81 \times 10^3$

Specific wheight of water $= \frac{8.77 \times 10^3}{9.81 \times 10^3}$

$$= 0.91$$

Specific Volume $= 1/\rho$

$$v = 1/\rho$$

$$v = \frac{1}{889} = \boxed{1.1 \times 10^{-3} \ m^3/kg}$$

$$S = vt$$

$$S = v \times 5 = 5v$$

Appendix A-15: Bolt Failure.

Mohammed Alhajri | MET 489 A | 12/3/19

Bolt failure

Total bolt = 6

Each bolt = Shear Strength

Bolt 1 = 500 Mpa

Bolt 2 = 300 Mpa

Bolt 3 = 400 Mpa

Plate thickness = 16 mm

$\sigma_b = P/A$

$A = d \cdot t$

$d = 12 \cdot mm$

$t = 10\ mm$

$A = 12 \times 10 = 120\ mm^2.$

Bolt 1 stress $= \dfrac{P}{0.012 \times 0.01}$

$P = 500 \times 10^6 \times 0.01^2 \times 0.01$

$\boxed{P = 66\,000\ N}$

$\sigma_t = \dfrac{PG}{bt}$

$b = 50\ mm$

Bolt 2 stress $= \dfrac{P}{0.05 \times 0.01}$

$\boxed{P = 200000\ N}$

Appendix A-16: Shear Failure.

Mohammed Alhajri | MET 492 A | 12/3/19

Shear failure

torsion = $P/_{A \times n}$

P= Load on top plate

Total plate = 1

$n = 1$

$\tau = P/_{A \times n}$

$300 \times 10^6 = P/_{A \times n}$

$A = \pi/4 \times (0.012)^2$

$$300 \times 10^6 = \frac{P}{\pi/4\,(0.012)^2}$$

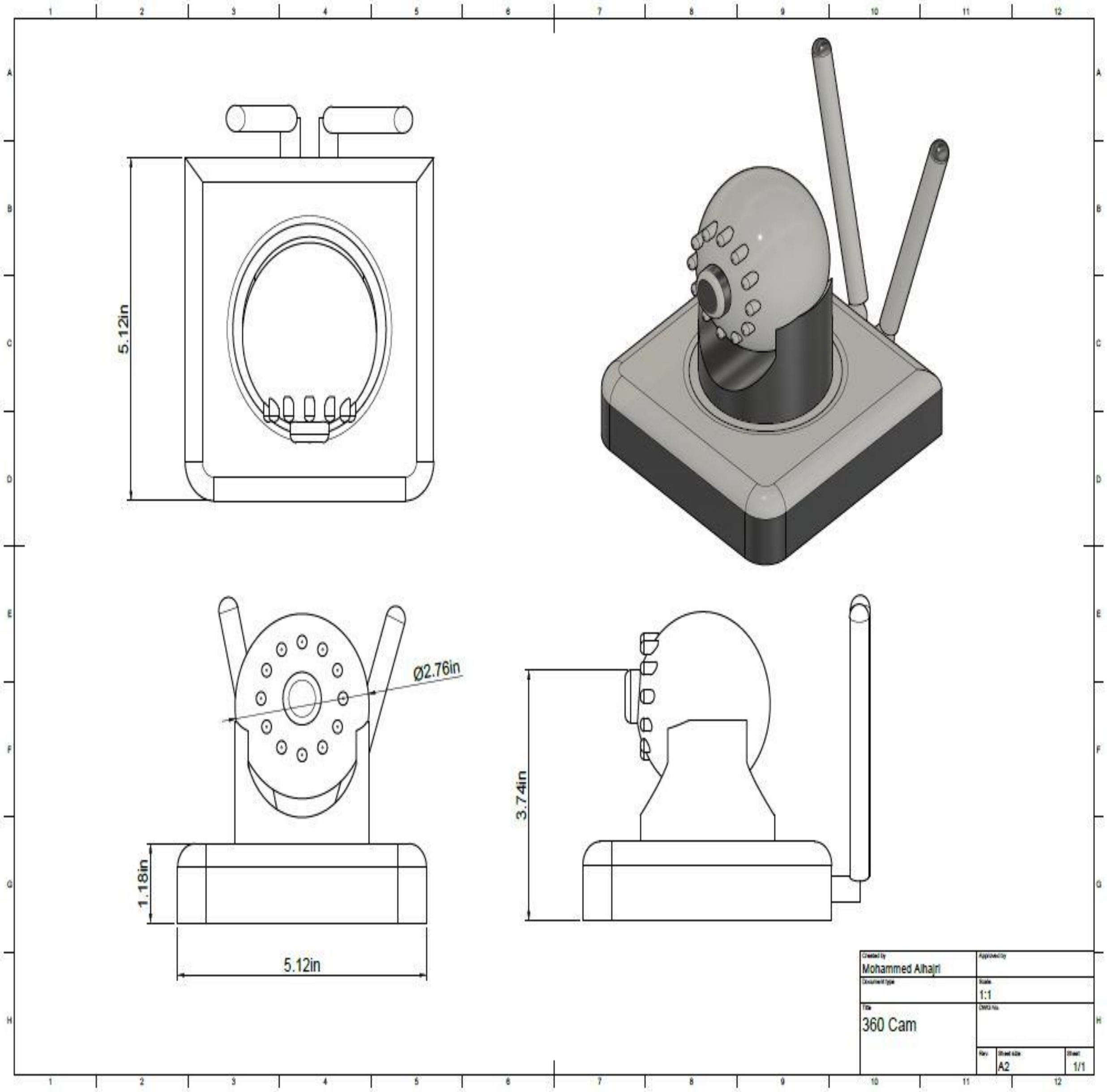
$P = \frac{\pi}{4} \times (0.012)^2 \times 300 \times 10^6$

$P = 33929.2$ N

Shear failure occurring first

Appendix B_ Drawing

B1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Ø2.76in
1.18in
5.12in
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Mohammed Alhajri
Approved by
Document type
Scale
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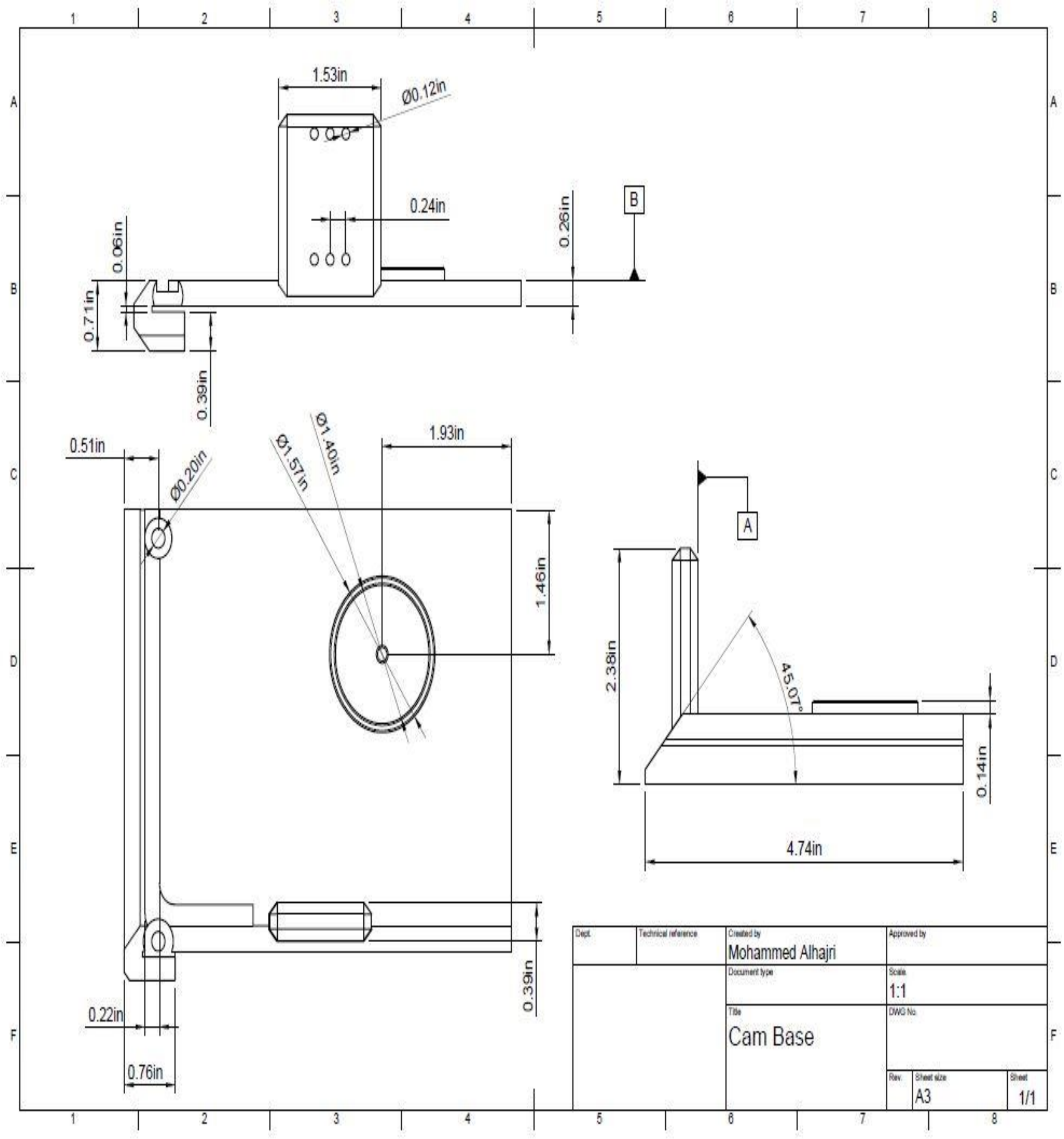
Title
360 Cam
DWG No.
Rev
Sheet size
A2
Sheet
1/1

B2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0.24in
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1.93in
1.46in
A
2.38in
45.07°
0.14in
4.74in
0.39in
0.22in
0.76in
Dept.
Technical reference
Created by
Mohammed Alhajri
Approved by
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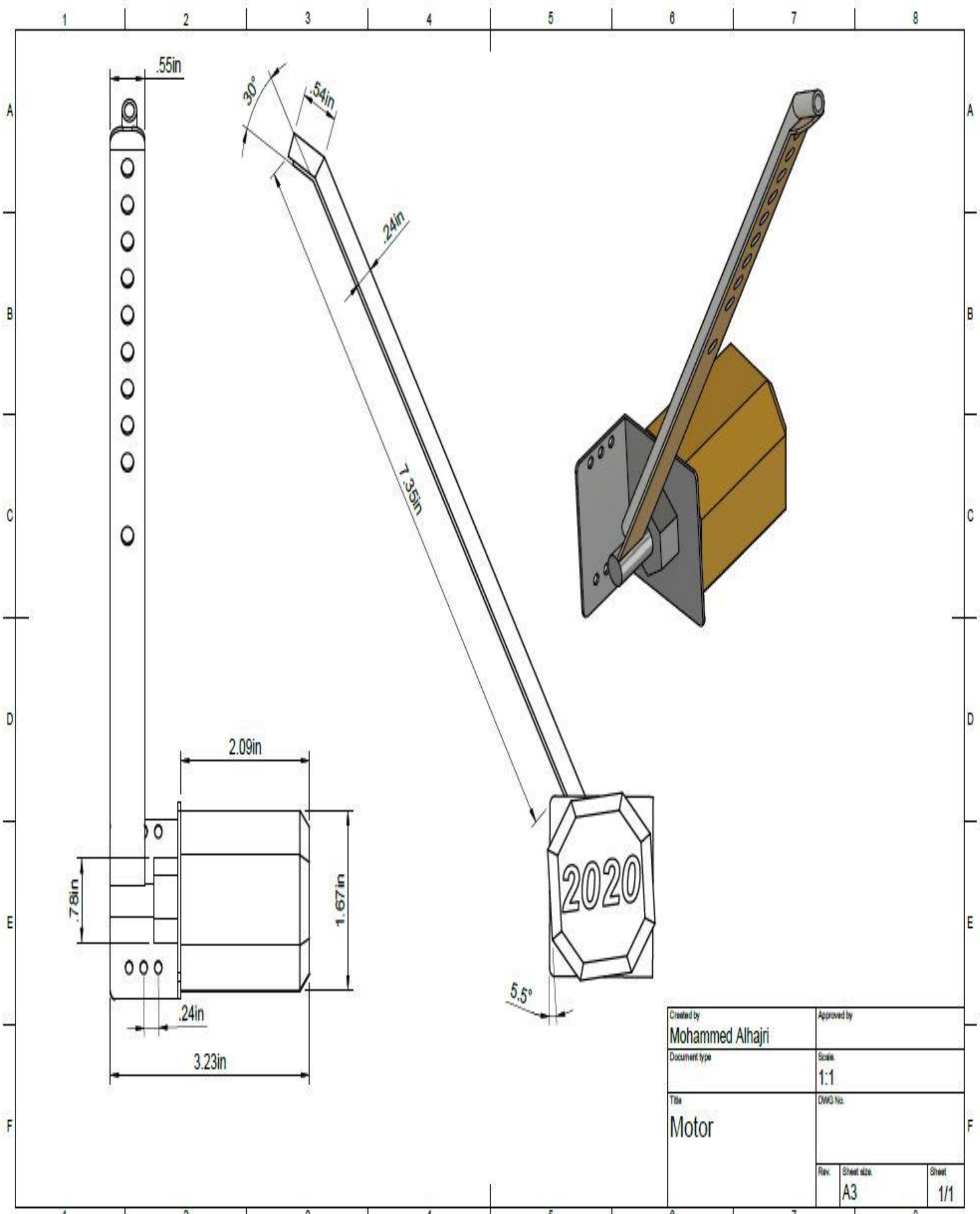
Scale
1:1
Title
Cam Base
DWG No.
Rev.
Sheet size
A3
Sheet
1/1

B3


.55in
30°
.54in
.24in
7.35in
2.09in
.78in
1.67 in
2020
5.5°
.24in
3.23in
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Mohammed Alhajri
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Scale
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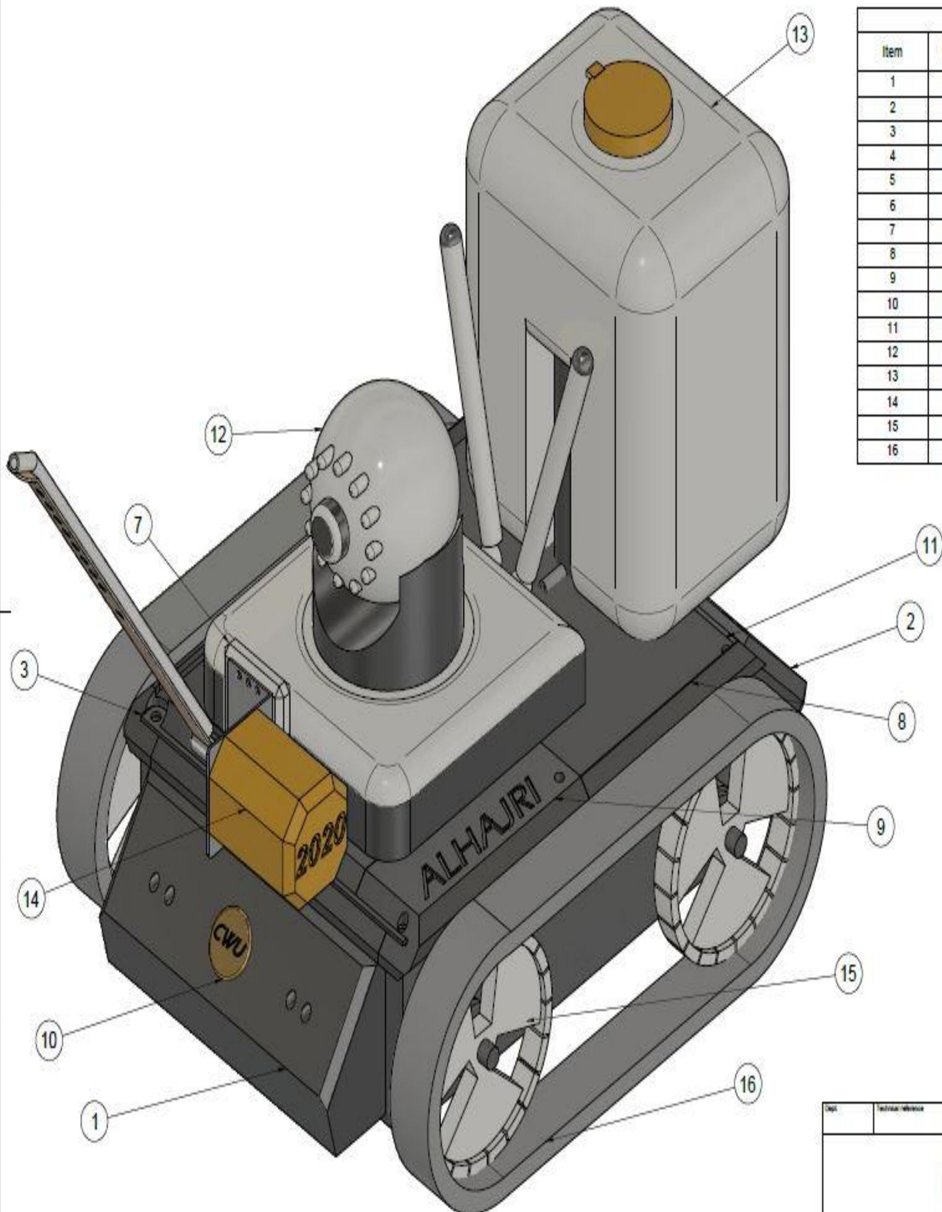
Title
Motor
DWG No.
Rev.
Sheet size
A3
Sheet
1/1

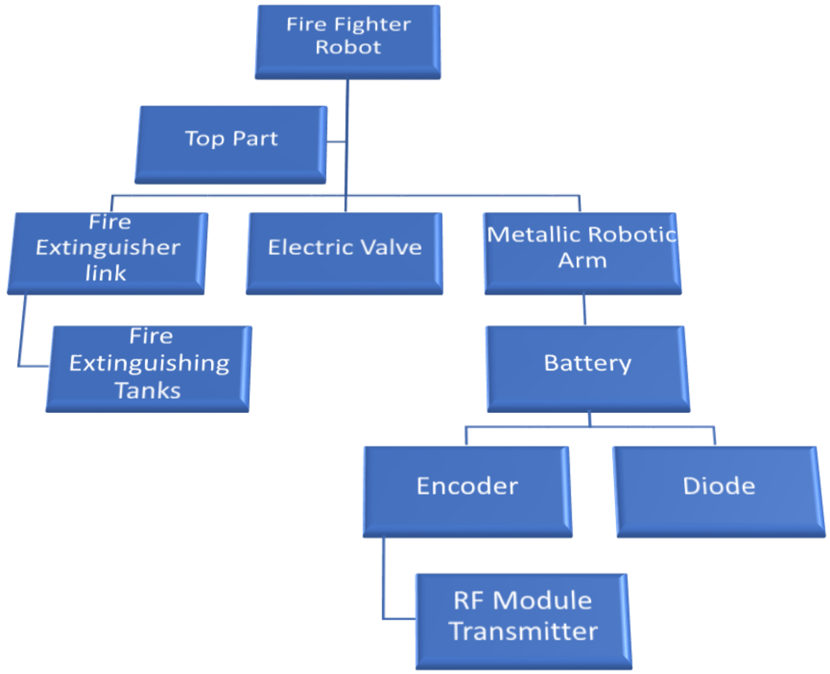
B4



Parts List			
Item	Qty	Part Number	Material
1	1	Front bumper	ABS Plastic
2	1	Back bumper	ABS Plastic
3	1	Cam Base	Steel
4	1	Batterie base	Steel
5	1	PCB base	Steel
6	1	Battrey	Steel
7	1	Motor holder	ABS Plastic
8	1	Spacer1	Steel
9	1	Spacer2	Steel
10	1	Antenna & Logo	Brass
11	1	Top cover	Steel
12	1	360 Cam	ABS Plastic
13	1	Fluid tank	Polypropylene
14	1	Motor	Steel, Mild
15	4	Wheel	ABS Plastic
16	2	Caterpillar tracks	Plastic

Dept.	Technical reference	Created by: Mohammed Alhajri	Approved by
		Document type	Scale: 1:1
		Title: Fire Fighter Robot	DWG No.
			Rev: A2	Sheet: 1/1

Appendix C_ Part List
C1-Top Part Tree Diagram



Appendix D_ Budget
D1

PART IDENT	PART DESCRIPTION	SOURCE	COST APPROX. (USD)

Fluid Tank	DN15-DN80 OD. 20 mm L= 5 mm	Amazon	$15
360 Camera	WiFi 360 Camera controlled by smartphone	Amazon	$40
3 motors	Low RPM, High torque gear motors 12V	Amazon	$160
Chained Wheel	52 Chain links L = 13 cm	Amazon	$25
Cart	Weight = 33 lb Max Load = 10 kg L = 8 cm W = 6 cm H = 3 cm	Amazon	$110
Battery	Exide 12V 65AH EP65-12	Amazon	$25

D2-Project Budget:

I	**Description**	**Cost**
1	Fluid valve	$15

2	360 Camera	$40
3	3 Motors	$160
Total		*$215*

Estimated Project Cost:
This table shows the estimated project cost which is $375. The price will include fluid valve, robotic arm, and fire extinguisher. A cost of 160$ will be spent for the bottom section parts. All parts can be found online.

Appendix E-Gantt Chart

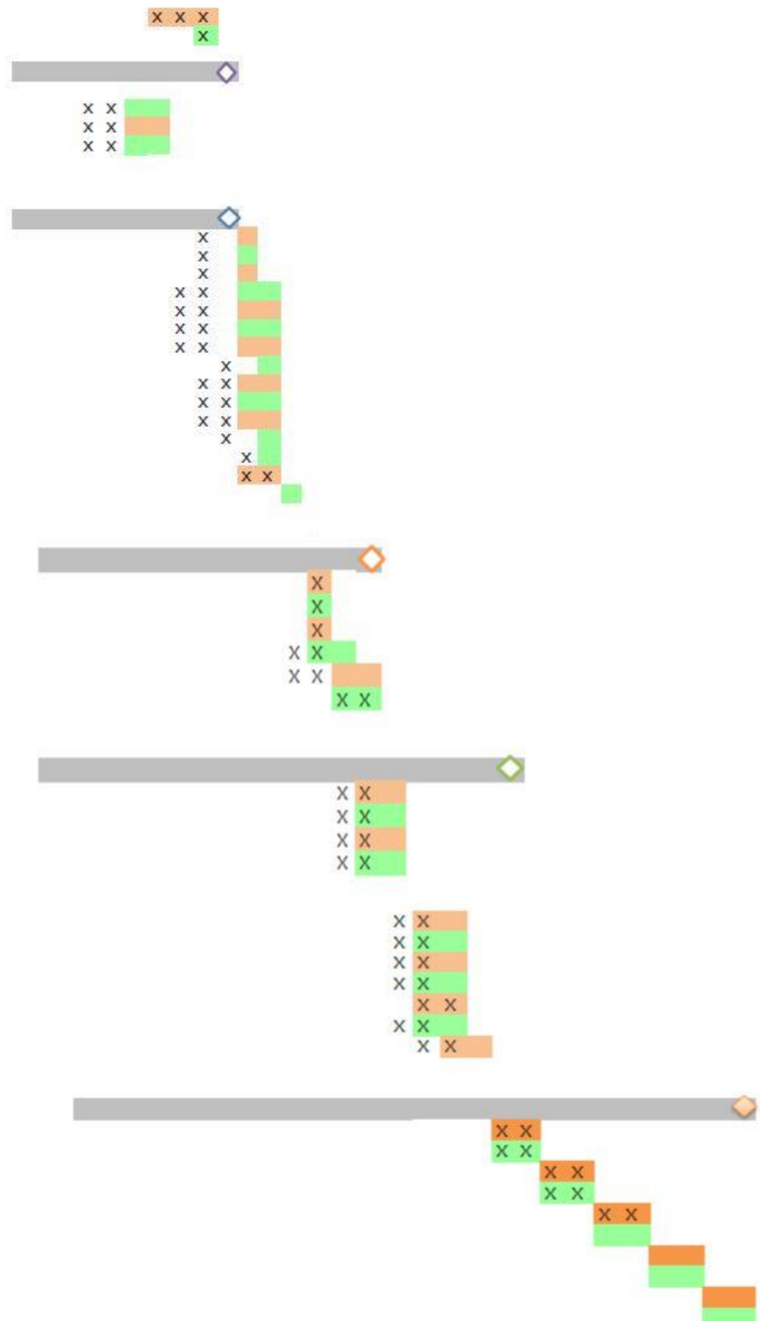
DEFINE HOW THE STUDENTS SHOULD INDICATE STARTING EARLY/LATE AND FINISHING EARLY/LATE
X to indicate work

EXAMPLE SCHEDULE FOR SENIOR PROJECT:
NOTE: STUDENTS MUST MAKE THEIR OWN SCHEDULE!!!!!!!!!!!!!
PROJECT TITLE: Fire Fighter Robot
Principal Investigator.: Mohammed Alhajri

Note: March x Finals
Note: June x Presentation
Note: June y-z Spr Finals

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	%Con	S	October	November	Dec	January	February	March	April	May	June
1	Proposal*													
1a	Outline	1	2		X									
1b	Intro	3	4		X	X								
1c	Methods	1	3		X	X								
1d	Analysis	1	3		X	X								
1e	Discussion	1	4		X	X X								
1f	Parts and Budget	1	1		X	X X X								
1g	Drawings	4	5		X	X X X								
1h	Schedule	4	6		X	X X X								
1i	Summary & Appx	4	5		X	X X X								
	subtotal:	20	33											
2	Analyses													
2a	Camera=>Geo	2	4			X X	X X							
2b	Robotic arm Anal=>Geo	4	6			X	X X X							
2c	Fluid tank=>Geo	3	6			X	X X X							
2d	Kinematic => Geo	2	3			X	X X X							
2e	Tolerance => Geo	3	2				X X X X							
	subtotal:	14	21											
3	Documentation													
3a	Part 1 Camera drawing	3	2				X X							
3b	Part 2 Robotic_Arm drawing	3	2				X X							
3c	Part 3 Camera_Base drawing	3	3				X X	X						
3d	Part 4 Front_Spacers drawings	3	4				X	X X						
3e	Part 5 Back_Spacers drawings	4	2					X X	X					
3f	Part 6 Remote drawings	8	7					X X	X					
3g	Part 7 Fluid_Tank drawing	2	1					X X	X					
3h	Part 8 Motor_Cover drawing	2	2						X X					
3i	Subassembly side	3	2						X X					
3j	Device robot drawing	4	3						X X X					
3k	Kinematic Check	3	2						X X X					

3l ANSIY14.5 Compl		3	3
3m Make Object Files		2	2
	subtotal:	43	35
4 Proposal Mods			
4a Project Robot Schedule		2	1
4b Project Robot Part Inv.		2	1
4c Crit Des Review*		3	2
	subtotal:	7	4
7 Part Construction			
7a Buy Part 360 Camera		1	1
7b Buy Part Robotic Arm		1	1
7c Buy Part Fluid tank		1	1
7d Make Part Camera base		10	8
7e Make Part front Spacer		8	5
7f Make Part Back Spacers		5	3
7g Make Part Motor holder		5	3
7h Set Up Part 360 Camera		2	1
7i Wiring Part 360 Camera		1	1
7j Wiring Part Fluid Tank		2	2
7k Paint Parts 3D printed		8	5
7l Take Part Pictures		2	2
7m Make Part PCB Remote		8	6
7n Update Website		8	7
7o Manufacture Plan*		4	
	subtotal:	66	46
9 Device Construct			
9a Assemble Camera base		1	1
9b Assemble Fluid Tank		1	1
9c Assemble Robotic Arm		1	1
9d Assemble Remote		2	2
9e Take Dev Pictures		2	2
9f Update Website		4	2
	subtotal:	11	9
10 Device Evaluation			
10a Test robot full assembeled body		3	2
10b Test Fluid tank		2	1
10c Test Camera		2	1
10d Test Robotic Arm		2	1
10e Test Remote control		2	1
10f Test Robot speed		1	1
10g Perform FULL Evaluation		2	5
10h Make upgrade plane		2	1
10i Make parts upgrades		10	8
10j Take Testing Pics		2	2
10k Update Website		5	4
	subtotal:	33	27
11 495 Deliverables			
11a Get Report Guide		5	3
11b Make Rep Outline		5	4
11c Write Report		8	5
11d Make Slide Outline		3	5
11e Create Presentation		5	5
11f Make CD Deliv. List		5	
11g Write 495 CD parts		5	
11h Update Website		4	
11i Project CD*		2	
	subtotal:	42	22
Total Est. Hours=		236	199
Labor$	100	23600	



=Total Actual Hrs

Appendix F

Expertise and Resources

Only the team members will be required for completing this project. Basic software knowledge will be required. The knowledge Engineering design process will be enough to complete this project.

Appendix G-Testing

Mohammed Alhajri | MET 489 A | 12/3/19

Appendix G testing

Testing of fire fighter cart

Case	Power (W)	Water throw (ft)
1	1 W	1 ft
2	1.5 W	2 ft
3	2 W	2.5 ft
3	3 W	3.5 ft
4	4 W	5 ft
5	4.5 W	5.8 ft
6	6.5 W	7 ft

Appendix H

MA

MOHAMMED ALHAJRI

hajrimdr@gmail.com | H: 509-902-9791 | 1917 W Peakview Dr, Ellensburg, WA 98926

Summary

I am a student at Central Washington University in Mechanical Engineering Technology major. I am a hardworking candidate and always willing to work under tight schedules and minimal supervision. I am currently 22 years old and I am always goal-oriented and always ready to achieve organizational set objectives. In addition, I am acquainted to all forms of emerging technologies pertaining the field of mechanical engineering. Lastly, I am able to communicate in Arabic and English as my second language.

Skills

- Good communication skills (Both written and oral skills)'
- Creative and innovative researcher.
- Ability to negotiate on behalf of the firm.
- Patient and hardworking person.
- Ability to identify and solve problems successfully.
- Collaborating with other employees towards achieving set targets.
- Skills to lead a team
- Speaking Arabic as the native language and English as the second language.

Experience

ARAMCO | Dhahran, Saudi Arabia
Security
03/2013 - 06/2015

In charge of securing sensitive properties inside ARAMCO Company.

Education and Training

Community College of Denver | Denver, CO
Associate of Science
2017

University of Wyoming | Laramie, WY
Bachelor of Science in Mechanical Engineering
2018

Central Washington University | Ellensburg, WA
Bachelor's Degree in Mechanical Engineering Technology
2020

Conference

Occupational Safety and Health Management Administration (OSHA) 2018 - Present
Security in ARAMCO 2014 – Present

JOB HAZARD ANALYSIS
{Manufacturing Fire Fighter Robot Parts}

Prepared by: Mohammad Alhajri	Reviewed by: Approved by:

Location of Task:	Central Washington University
Required Equipment / Training for Task:	Milling machine operations, Operation of the drill press, Operation of belt sander, 3D printing operations and First aid.
Reference Materials as appropriate:	SDS for the spray paint https://www.krylon.com/document/SDS/en/US/724504016014

Personal Protective Equipment (PPE) Required (Check the box for required PPE and list any additional/specific PPE to be used in "Controls" section)						
Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
☒	☒	☒	☒	☒	☒	☐
Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.						

TASK	TASK DISCRIPTION	HAZARDS	CONTROLS
CNC MILLING	Set up of 3D mill	Injury to hands from milling blades.	Never disconnect safety shields from milling blades.
		Hearing damage from noise of machine operation.	Wear hearing protection, such as ear plugs, if operating machine for periods extending more than 10 minutes.
	During milling	Possible eye injury from wire stitches thrown out by milling blade.	Wear safety glasses during operation.
		Crushing finger hazard from book clamp.	Do not hold book at spine when activating book clamp. Hold book at the face.

PRESS DRILLING	Clean the table.	Eye injury from metal debris.	Wear eye protection. Do not use compressed air.
	Load the vise.	Foot injury if the vise falls	Secure the vise on the table with T-pins.
		Finger pinching while sliding the vise	Don't let fingers get under the vise unless lifting it from the table.
	Lock the table in place.	Back strain	Don't lean over the table to twist the lock handle.
	Load the bit.	Hand injury from the bit	Wear gloves. Don't hold on the end of the bit.
	Feed the drill with the feed.	Injury caused by breaking the bit	Feed with the appropriate pressure. Use the appropriate bit for the type of metal. Wear eye protection.
		Eye or skin damage from cutting oil	Use the lowest RPM. Wear eye protection. Wear a long sleeved shirt.
		Hand injury from the exposed pulley near the feed handle	Make sure a pulley guard is in place. Don't push the feed handle toward the pulley.
	Unload the vise.	Foot injury if the vise falls	Leave the vise secure on the pins.
BELT SANDING	Check condition of belt.	Abrasion of fingers and hands	Avoid contact with belt edge or surface.
	Start sander.	Flying sawdust	Wear safety glasses or face shield.
	Align materials flat on table.	Pinching fingers or hand	Keep fingers and hands away from pinch points.
	Contact material with belt sander.	Cutting fingers or hand	Avoid contact with belt edge or surface.
		Flying sawdust	Wear safety glasses or face shield.
	During printing	Injury due to touching of	Attend the UP! 3D Printer

3D PRINTING		nozzle tip temperature	tutorial qualification training. Wear leather gloves and stay away from the nozzle head as the printer prints.
	Removal of printed part	Injury due to poor removal of part from platform bed Cut or eye damage due to sharp/rough edges and small plastic pieces while removing support material on part. Injury due to platform bed temperature	Wear leather gloves. Use proper tooling for removal of part following the tutorial training. Wear leather gloves, safety glasses, and avoid handing rough edges. Wear leather gloves.
SPRAY PAINTING	Spray paint parts	Toxic fumes	Wear safety glasses and a dust mask.